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Shoulder Check: Investigating Shoulder Injury Rates, Types, Severity, Mechanisms, and Risk Factors in Canadian Youth Ice Hockey

--Manuscript Draft--

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Abstract:	Objective: To describe shoulder-related injury rates, types, severity, mechanisms, and risk factors in youth ice hockey players during games and practices. Study Design: Secondary analysis of data from a 5-year prospective cohort study Safe-to-Play (2013-2018). Subjects: Overall, 4419 individual players (representing 6585 player-seasons; 3806 males: 613 females) participated. During this period, 118 primary shoulder-related game injuries and 12 practice injuries were reported. Outcome Measures: Injury surveillance data was collected from 2013-2018 (time-loss or medical attention injuries). Descriptive statistics were calculated, and injury rates with 95% CI were estimated using Poisson regression. An exploratory multivariable mixed-effects Poisson regression model (clustering by team and offset by exposure hours) examined risk factors. Results: The shoulder injury rate was 0.70 injuries/1000 game-hours (95% CI 0.37-1.33) and 0.07 injuries/1000 practice-hours (95% CI 0.04-0.12). Two-thirds of game injuries (n=79, 69%) resulted in >8 days of time-loss, and more than one-third (n=44, 39%) resulted in >28 days of time-loss. An 82% lower rate of shoulder injury was associated with policy prohibiting body checking compared to leagues allowing body checking [IRR=0.18 (95% CI 0.10-0.32)]. A higher shoulder injury rate was seen for those who reported any injury in the last 12-months compared to those with no history [IRR=2.32 (95% CI 1.57-3.41)]. Conclusions: Most shoulder injuries resulted in more than one week of time-loss. Risk factors for shoulder injury included participation in a body checking league and history

	of injury in the previous 12 months. Further study of prevention strategies specific to the shoulder may merit further consideration in ice hockey.

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Conclusions: Most shoulder injuries resulted in more than one week of time-loss. Risk factors for shoulder injury included participation in a body checking league and history of injury in the previous 12 months. Further study of prevention strategies specific to the shoulder may merit further consideration in ice hockey.

Keywords: ice hockey, youth, injury prevention, shoulder, sport injury

Introduction

Ice hockey is a collision sport commonly played by youth across Canada. As of 2020, more than 600 000 Canadian youth (ages 5-17 years) were registered to participate through Hockey Canada (1). Participation in sport has vast benefits for youth including improved physical, social, and mental well-being (2-5). On the other hand, participation in ice hockey carries a risk of injury and high injury rates have been reported (6). Further, these injuries may lead to substantial negative consequences for youth such as functional impairment, decreased quality of life, as well as social and/or emotional stress (7-9). Overall, injury rates in youth ice hockey in Canada have been reported to be between 2.16 to 7.98 injuries/1000 game-hours (depending on age of cohort and body checking policy) (10-12). Ice hockey injuries are also known to account for the highest proportion (16%) of youth emergency department visits related to collision sport (12).

Being a collision sport, a common mechanism of injury in ice hockey is body checking, which is a direct, immediate contact (in an opposite or perpendicular direction) with another player (13). In ice hockey, the intention of body checking is to 'separate an individual from the puck' and 'create space' (14). Injuries however, are a known and unfortunate consequence (11, 15-17). In 2013, body checking policy changes were introduced by Hockey Canada to prohibit body checking nationally in the younger age groups (under-13) as well as regionally in sub-elite divisions of play in the following years (under-15, under-18), with a target to reduce the burden of injury. Even when considering the inherent risks for intentional or unintentional contact associated with the fast-paced and collision nature of ice hockey, shoulder-related injuries have been reported as a common injury across various youth age groups and skill levels. Shoulder injuries are of specific research interest as the shoulder is the most common point of contact for both the player delivering and the player receiving a body check. Emery et al (2020) reported a shoulder injury rate (IR) of 0.74 injuries/1000 game-hours (95% CI 0.00-2.20) among under-15 Canadian players in a body-checking league, which accounted for 9% of all injuries (n = 12/129) (10). Notably, no shoulder injuries were observed when body checking was prohibited from game play in the under-15 age group (n = 0/31 injuries) (10). More recently in 2022, a shoulder IR of 2.31 injuries/1000 game-hours (95% CI 1.64-3.17) was observed in an under-18 body checking league (n = 38/213) and 0.26 injuries/1000 game-hours (95% CI 0.03-0.93) in a non-body checking league (18). In game play permitting body checking, shoulder injuries accounted for the second highest proportion (17.8%) of all injury locations (following the head/face) (19). To date, however, shoulder-specific research in the context of youth ice hockey remains sparse, and without unified validated surveillance methods or injury definitions being used broadly across shoulder-specific research. A comprehensive understanding of the etiology, potential risk factors, and mechanisms for injury from robust, high-quality ice hockey studies is needed. This currently represents a knowledge gap, as research attention has previously focused on concussion and injuries of the lower extremity. As such, the primary objective of this study was to describe shoulder injury rates, locations, types, severity, and mechanisms in youth female and male ice hockey players ages 10-17 during games and practices. An exploratory objective was to explore potential risk factors (including body checking policy, injury history, biological sex, playing position, and player size) on shoulder injury occurrence in youth female and male ice hockey players.

Methods

Study Design

This is a secondary analysis of a prospective longitudinal cohort study (10,11,15,16,18). Injury surveillance was implemented across four major Canadian cities from 2013 to 2018. Ethical approval was obtained from the local Research Ethics Board ([redacted]).

Participants

Study participants included youth in the under-13 (U13; ages 11-12), under-15 (U15; ages 13-14), and under-18 (U18; ages 15-17) age groups. Inclusion criteria for eligible participants were: (1) participation on a team of female and/or male ice hockey players; (2) aged 10-17 years old at baseline; (3) completed both informed parental consent and player assent; (4) the team was registered to participate through their local regulatory body; (5) the teams' head coach agreed to participate; and (6) a team designate or the individual athlete agreed to collect/record relevant injury and participation data.

Procedures

Validated injury surveillance methodology was conducted (13, 19). Study measures included Injury Report Forms (IRFs), a Preseason Baseline Questionnaire (PBQ), and a Weekly Exposure Sheet (WES).

Preseason Baseline Questionnaires (PBQs)

Preseason Baseline Questionnaires (PBQs) were completed by participating athletes yearly and included demographics (e.g., age, biological sex), injury history [i.e., injuries from any activity (including outside of sport) with more than 1 day of time-loss from activity in the previous 12 months or need for medical attention], and medical history (e.g., current medications, presence of systemic or chronic diseases/disorders, any known psychological diagnoses).

Subject Characteristics

Athlete height (cm) and weight (kg) were collected yearly during baseline assessments by trained research assistants according to a universal study protocol (RA's) or self-reported in the PBQ.

Weekly Exposure Sheet (WES) and Injury Report Forms (IRFs)

Following reports of an injury, an Athletic Therapist or Physiotherapist followed up with athletes either in-person or over the phone and completed an Injury Report Form (IRF). The IRF's outlined the nature of the injury sustained, including written descriptions of the injury mechanisms, and severity (time-loss from ice hockey, if any). Weekly Exposure Sheets (WES) measured an athlete's participation hours in games and practices. The WES was collected by a team designate (e.g., athletic therapist, coach, manager, team administrator, parent, player). Data collected was specific to each athlete.

Injury Definitions

This study used an inclusive injury definition that considered any player who sought medical attention (any injuries seen by an athletic therapist, physiotherapist or physician), was unable to continue in a game or practice session or reported time-loss from hockey. Shoulder related injuries included any clavicular, scapular, acromioclavicular joint, rotator cuff, or shoulder joint, and surrounding tissue impairment.

Statistical Analysis

Participant baseline characteristics were stratified by shoulder injury outcome and biological sex. More specifically, the following categories were considered to describe the primary outcome variable: those who reported at least one shoulder injury, those who reported any other injury (i.e., at least one injury that was not related to the shoulder), and those who did not report an injury during the study period. Shoulder injuries in this analysis were operationalized to include only an athlete's primary injury related to the shoulder joint. If an athlete reported a secondary injury (such as a concussion, for example) in addition to their shoulder injury, this was coded as a shoulder injury. With respect to the females in the dataset, sex was self-reported at baseline or assumed based on league participation (i.e., those who participated in a female-only league). Descriptive statistics, frequencies, and proportions (stratified by biological sex) were calculated. Shoulder injury rates (IR) were estimated using Poisson regression with clustering by team and offset by exposure hours (# injuries/1000 game and practice-hours; with the corresponding 95% CIs). Injury types, severity, timing, and mechanisms were reported as frequencies, proportion of injuries reported, and injury rates (with 95% CIs) as they were observed in youth ice hockey. Crude injury rates per 1000 hours of game exposure were reported in females due to the low sample size. Multiple imputation by chained equations (MICE) was used to impute all missing covariate data (30 imputations completed). MICE imputation considered height, weight, body checking policy, injury history in the previous 12 months, playing position, and level of play.

An exploratory multivariable Poisson regression model adjusting for body checking policy (categorical: permitted, not permitted), weight (continuous: kilograms), biological sex (categorical: male or female), history of previous injury in the past 12 months (binary: yes/no), level of play (binary: elite ~top 30% by division of play, non-elite ~lower 70% by division of play) accounting for clustering by team and offset by exposure hours with one mixed-effect at the team level, was used to examine potential risk factors for game-related shoulder injuries. Statistical significance was considered at an alpha level of $p<0.05$.

Results

Overall, 4419 individual players (representing 6585 player-seasons; 3806 males, 613 females, 137 prefer not to respond/missing) were recruited over the five-year ice hockey longitudinal cohort study. During this period, 118 primary shoulder-related game injuries and 12 primary shoulder-related practice injuries were reported. The male shoulder IR observed was 0.70 injuries/1000 game-hours (95% CI 0.37-1.33) and 0.07 injuries/1000 practice-hours (95% CI 0.04-0.12). Among females, 6 shoulder injuries were reported across 5 female participants (4 game and 2 practice injuries) during the study period. No participants that sex was missing or reported as prefer not to respond reported a shoulder injury.

Baseline demographics stratified by shoulder injury, any other injury (concussion or non-shoulder musculoskeletal), and those who did not report an injury during the study are presented in Table 1. The frequency of missing covariate data is reported in this table and ranged from 5% to 28%. The most common game injury types for males were fractures (n=38, 33%), joint swelling/ligament sprain (n=36, 29%), and muscle strain (n=18; 16%) (Table 2). For females, the most common game injury types were joint swelling/ligament sprain (n=2, 50%), fracture (n=1, 25%), and dislocation (n=1; 25%) (Table 2). Sudden onset injuries associated with contact from another player or the environment was the most common injury mechanism for both males and females (Table 3). Most shoulder injuries occurred during games (114 game vs. 10 practice injuries for males; 4 game vs. 2 practice injuries for females). Subsequent time-loss from ice hockey as a result of shoulder-related injury was substantial (Table 4). With respect to the injury severity, median time-loss from shoulder-related injury was 19 days (IQR 6-46 days) for males, and 12 days (IQR 3-69 days) for females. Over two-thirds of male game injuries (n=79, 69%) resulted in more than 8 days of time-loss, and more than one-third (n=44, 39%) resulted in more than 28 days of time-loss from ice hockey.

Considering the exploratory multivariable mixed effects Poisson regression model (Table 5), an 82% lower rate of shoulder injury was associated with policy prohibiting body checking [IRR=0.18 (95% CI 0.10-0.32)]. A two-fold higher shoulder IR was seen for those who had reported a history of any musculoskeletal injury or concussion in the last 12-months [IRR=2.32 (95% CI 1.57-3.41)]. Goaltenders demonstrated a lower shoulder injury rate relative to forwards [IRR=0.32 (95% CI 0.11-0.87)]. Biological sex, level of play, and weight were not associated with shoulder IRs (Table 5).

Discussion

This prospective cohort study sought to comprehensively describe the shoulder-specific injury patterns in Canadian youth ice hockey players over a five-year period. The primary finding from this study was the high incidence of game shoulder-related injury at 0.70 injuries/1000 game-hours (95% CI 0.37-1.33) among males. Shoulder-related injuries most commonly occurred as a result of direct contact with another individual, and these individuals missed substantial time from ice hockey as a result of their shoulder injury. A striking observation from this study was that policy disallowing body checking was associated with an 88% lower rate of shoulder injury compared to leagues permitting body checking. It is therefore important to consider policy concomitantly alongside potential injury risk factors when considering efforts to reduce the burden of shoulder injury in youth ice hockey.

The observations from this study are consistent with the findings of Emery et al. (2010) that sought to evaluate the effectiveness of body checking policy permitting body checking in games, where body checking leagues observed a three-fold increased risk of game-related injury compared to non-body checking leagues. Emery et al. (2020) reaffirmed this position following a prospective cohort evaluation where policy changes prohibiting body checking was associated with a 54% decrease in all injuries in players 13-14 years. These findings are also consistent with multiple systematic reviews and prospective cohort studies across age groups suggesting that body checking is associated with both musculoskeletal injury and concussion occurrence (11, 12, 15, 19, 20). As it appears that participation in a non-body checking leagues conferred a strong protective effect on shoulder IRs, this signifies the need for further policy implications and prevention strategies to be considered as it may result in both injury reductions and health care cost-savings for youth ice hockey players (21, 22).

An athlete's history of a previous musculoskeletal injury or concussion in the previous 12 months was identified as a shoulder injury risk factor among ice hockey players. It may be hypothesized that these players are returning to sport too soon, potentially placing them at risk for further or subsequent tissue damage. While these athletes may even be 'clinically' healed or 'cleared for return to play' by a qualified healthcare practitioner, they may still suffer from lasting or long-term effects from their injury which persist (such as muscle atrophy or impaired joint proprioception). Alternatively, these athletes could also be inherently predisposed to injury in general, based on their individual risk profile rather than a single previous injury. Such phenomenon as considering previous sport-related injury or concussion as an injury risk factor has been previously outlined in various papers and a systematic review with respect to youth sport (23-25). These studies identified that previous injury or concussion is a risk factor for future injury or subsequent recurrent injury. Future studies considering return to play timelines following shoulder injury would serve as an asset to fill in gaps in the literature with respect to shoulder IRs.

Game-related shoulder injuries appeared to result in substantial time-loss from sport for youth ice hockey players. Considering that shoulder injuries have been reported to be the second most common injury in body checking-permitted ice hockey leagues (following concussion), the potential lasting effects of a shoulder injury may have real life impacts on athletes, and this merits further scrutiny in future studies(18).

This study serves to describe current shoulder-related injury trends in Canadian youth ice hockey. Overall, the findings of this study were relatively consistent with what has been previously observed. In particular, findings related to the timing of injury aligned with various previously published works where shoulder injuries were more common in games than practice exposures (10, 11, 15-17, 26, 27). With respect to the shoulder injury literature, injuries are known to occur with contact, a phenomenon that was once again observed (12). In contrast however, player size (namely weight) has typically been known to be associated with higher injury rates in ice hockey (15-17). Subjectively, players have been known to report more any injury occurrence during contact with a larger player than them in boy's collision sports (28). Nonetheless, information gained from this study has the potential to inform the formulation and design of shoulder injury prevention strategies and future body checking policies that will make youth sport a safer space for females and males participating in youth ice hockey.

As missing covariates accounted for nearly a third of some variables (up to 28%), data imputation was requisite to improve statistical power. Multiple imputation is considered a reliable method to reduce sources of error and increase precision within a given dataset (29, 30). Notwithstanding, a small count of shoulder injuries among certain strata can be noted (in particular those who played goalie and females). It is a limitation that only 6 shoulder injuries were reported across 5 female participants (4 game and 2 practice injuries) during the study period. Risk factor analysis, specifically, among female ice hockey players was not possible due to low sample size. This may directly impact the generalizability of these results to female ice hockey programs, so further study in this population is needed to identify shoulder injury risk factors. A low number of practice injuries were also observed in this cohort (n=12) so a separate analysis was not feasible. This limits our ability to draw conclusions with respect to risk factors for shoulder injuries occurring in practice. The use of an exploratory multivariate model to consider the shoulder-specific observations in this data is a strength, as it likely results in a more precise estimation (by adjusting for potentially confounding factors within the model and reducing the standard error of the residuals). As this was a secondary data analysis, continued follow-up for missing or incomplete data was not possible. Efforts were made by the study team to minimize missing data through phone calls directly to participants, and regular check-ins with the assigned team designates at the time of data collection. Being a secondary analysis, this also limited the selection of variables available for the risk factor analysis, with most risk factors being non-modifiable and not shoulder-specific. A potential source of selection bias in the cohort is that more serious injuries (such as season-ending injuries or those requiring surgical intervention) may have been more likely to be lost to follow-up if a player left the team or sport. With multiple players participating in more than one season, it would have been ideal to also cluster by individual within the multiple model but such crossed-effects models are computationally intensive and prohibitively time consuming.

Conclusions

This study demonstrates that shoulder injury has a high injury incidence rate in youth ice hockey. A striking observation was that most shoulder injuries resulted in more than one week of time-loss from sport. Risk factors for shoulder injury included participation in a body-checking league and previous history of any injury in the previous 12 months. Goaltenders were protected relative to forwards. Although body checking policy is known to be associated with all injury rates, further study of policies and prevention strategies specific to the shoulder merit further consideration and evaluation.

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Table 1. Baseline characteristics stratified by injury outcome and biological sex.

	Shoulder injury (n=130)		Non-shoulder Injury (n=1059)		Uninjured (n=5396)	
	Males	Females	Males	Females	Males	Females
Height (cm; median, IQR)	171 (165-177	164 (159-171)	170 (158-178)	164 (159-170)	164 (154-175)	162 (156-168)
Missing (n, %)	35 (28)	1 (20)	261 (28)	25 (19)	1374 (27)	72 (16)
Weight (kg; median, IQR)	64 (53-73)	62 (54-67)	59 (46-68)	57 (50-63)	53 (43-65)	52 (45-59)
Missing (n, %)	34 (27)	1 (20)	266 (29)	29 (21)	1315 (27)	62 (14)
Age group (%)						
Under-13 (11-12 years)	5 (4)	0	136 (15)	18 (13)	1290 (26)	119 (26)
Under-15 (13-14 years)	58 (46)	1 (20)	460 (50)	71 (52)	2242 (46)	242 (50)
Under-18 (15-17 years)	62 (50)	4 (80)	326 (35)	47 (35)	1386 (28)	111 (24)
Missing (n)	0	0	1 (0)	0	0	0
Body checking policy (%)						
Permitted	113 (90)	0	655 (71)	7 (5)	2374 (48)	36 (8)
Not Permitted	12 (10)	5 (100)	244 (26)	126 (93)	2397 (49)	412 (90)
Missing (n, %)	0	0	24 (3)	3 (2)	152 (3)	9 (2)
Playing position (%)						
Forward	76 (61)	3 (60)	501 (54)	74 (54)	2620 (53)	237 (52)
Defence	39 (31)	1 (20)	296 (32)	49 (36)	1516 (31)	152 (33)
Goalie	4 (3)	0	55 (6)	6 (4)	450 (9)	52 (11)
Missing (n, %)	6 (5)	1 (20)	71 (8)	7 (5)	337 (7)	16 (4)
Previous injury in the last 12 months (%)						
No	40 (32)	0	359 (39)	40 (29)	2614 (53)	214 (47)
Yes	67 (54)	4 (80)	378 (41)	66 (49)	1467 (30)	152 (33)
Missing (n, %)	18 (14)	1 (20)	186 (20)	30 (22)	842 (17)	91 (20)

Table 2. Shoulder injury types in games, stratified by biological sex.

	Male Injury Types (n=114)		Female Injury Types (n=4)	
Injury Type	**Frequency (%)**	**Injury Incidence Rate [injuries/1000 game-hours] (95% CI)**	**Frequency (%)**	**Crude Injury Incidence Rate [injuries/1000 game-hours]**
Fracture	38 (33)	0.24 (0.01-0.54)	1 (25)	0.05
Joint Swelling/Ligament Sprain	36 (29)	0.23 (0.09-0.49)	2 (50)	0.10
Muscle Strain	18 (16)	0.11 (0.06-0.28)	0	0
Dislocation	12 (11)	0.08 (0.03-0.14)	1 (25)	0.05
Bruise	10 (9)	0.06 (0.02-0.13)	0	0
Missing	0	-	0	0

*** Injury incidence rate calculated using Poisson regression (clustering by team and offset by exposure hours). Crude IR reported for females due to low sample size.**

Table 3. Shoulder injury mechanisms in games, stratified by biological sex.

	Male Injury Mechanisms (n=114)		Female Injury Mechanisms (n=4)	
Injury Mechanism	**Frequency (%)**	**Injury Incidence Rate [injuries/1000 game-hours] (95% CI)**	**Frequency (%)**	**Crude Injury Incidence Rate [injuries/1000 game-hours]**
Sudden Onset: Contact with another player or the environment	93 (82)	0.58 (0.29-1.47)	3 (75)	0.15
Sudden Onset: No contact with another player or the environment	10 (9)	0.06 (0.02-0.34)	0	0
Gradual Onset: Repetitive Injuries	3 (1)	0.02 (0.01-0.09)	0	0
Missing	8 (7)	0.05 (0.03-0.84)	1 (25)	0.05

*** Injury incidence rate calculated using Poisson regression (clustering by team and offset by exposure hours). Crude IR reported for females due to low sample size.**

Table 4. Injury severity defined by time-loss from ice hockey following game-shoulder injury, stratified by biological sex.

	Male Injury Severity (n=114)		Female Injury Severity (n=4)	
Injury Severity (time-loss)	**Frequency (%)**	**Injury Incidence Rate [injuries/1000 game-hours] (95% CI)**	**Frequency (%)**	**Crude Injury Incidence Rate [injuries/1000 game-hours]**
Slight (0-1 days)	7 (6)	0.04 (0.03-0.07)	1 (25)	0.05
Minimal (2-3 days)	11 (10)	0.07 (0.03-0.17)	0	0
Mild (4-7 days)	17 (15)	0.11 (0.03-0.24)	1 (25)	0.05
Moderate (8-28 days)	35 (31)	0.22 (0.13-0.39)	1 (25)	0.05
Severe (>28 days)	44 (39)	0.27 (0.20-0.42)	1 (25)	0.05
Missing	0	-	0	0

*** Injury incidence rate calculated using Poisson regression (clustering by team and offset by exposure hours). Crude IR reported for females due to low sample size.**

Table 5. Adjusted Injury Incidence Rate Ratios (IRRs) for game-related injuries based on multiple Poisson regression (clustering by team and offset by exposure hours) with one mixed effect at the team level. MICE imputation used.

Potential Risk Factor (n=130)		Injury Incidence Rate Ratio (95% CI)
Body Checking Policy	Permitted	1 (Reference)
	Not Permitted	**0.18 (0.10-0.32)**
Weight		1.01 (0.99-1.025)
Previous Injury (last 12 months)	No	1 (Reference)
	Yes	**2.32 (1.57-3.41)**
Level of Play	Elite	1 (Reference)
	Sub-elite	0.83 (0.56-1.22)
Playing Position	Forward	1 (Reference)
	Defense	0.87 (0.59-1.27)
	Goalie	**0.32 (0.11-0.87)**
Biological Sex	Male	1 (Reference)
	Female	1.12 (0.42-3.00)

*** Incidence Rate Ratios (IRRs) calculated using multiple Poisson regression (clustering by team and offset by exposure hours).**